TITANIUM - AN ARSENAL IN PROSTHODONTICS

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Abstract
Biocompatibility, resistance to corrosion and excellent mechanical properties makes Commercial pure titanium (cpTi) the material of choice of dentistry. Apart from its favourable characteristic commercially pure titanium has several shortcomings too. This paper thus highlights the various aspects of commercially pure titanium which makes its an ideal material for clinical applications.
Key Words: Corrosion, Implant, Osseointegration**,** Surface characteristics, Titanium.

INTRODUCTION

In Dentistry various metals and materials are used with the advancements of their techniques and utility. Prosthodontic success depends mainly on the type of material used which plays a major role in deciding the life of the restoration. Titanium is one such metal used in prosthodontics since last 6 decades in various treatment modalities mainly in implants. In 1790, Reverend William Justin Gregor from England was the first to discover Titanium, while working with magnetic sand. Later, German chemist Heinrich Klaproth, isolated titanium from rutile (TiO2). In 1795 this mineral was named titanium in the honor of Titans, sons of Uranus and Gaya, from the Greek mythology [1]. In 1887 the impure metallic titanium was produced[2] .But only after 1946 when William Justin Kroll produced commercial titanium by reducing of titanium tetrachloride (TiCl4) with magnesium at 8000C in an atmosphere of argon metallic titanium was used outside laboratory. This process which is universally known as the Kroll Process has become the most popularly used method to obtain commercial titanium. By this process titanium sponge(Fig. 1), which is a porous product is obtained which when subsequently purified forms the commercial product. [3]

Fig. 1:Titanium sponge, made by the Kroll process

Titanium is the ninth most commonly found element and fourth most frequently found metal in earth but is not found freely in nature. It is found mostly in the igneous rocks and the sediments obtained from these rocks but also from minerals like ilmenite, leucoxene and rutile. Approximately 300 million tons of global titanium reserves are estimated which are mostly found in Australia, Scandinavia, United States, Canada, Finland and Malaysia. [4]

FUNDAMENTAL ASPECTS OF TITANIUM

Titanium: Abbreviation Ti; is the 22nd element of the periodic table.
SYMBOL :Ti
ATOMICNUMBER :22
ATOMICMASS :47.88
FAMILY :Group(IVB) Transition metal
PRONUNCIATION : ty-TAY-nee-um

Isotopes

Titanium-46, titanium-47, titanium-48 (most abundant), titanium-49, and titanium-50 are the five isotopes of titanium that exists naturally.
Compounds
Titanium dioxide (TiO2) and titanium tetrachloride (TiCl4) are the two most important compounds of titanium.[5]

CLASSIFICATION OF TITANIUM AND ITS ALLOYS

Addition of traces of oxygen, iron and nitrogen greatly varies the properties of pure Ti and Ti alloys. There are four grades of commercially pure titanium: ASTM I to IV- based on the addition of the trace elements during purification procedure.
cp grade I
cp grade II
cp grade III
cp grade IV
Ti-6Al-4V and Ti-6A1-4V are the two types of titanium alloys used in dentistry.

CRYSTALLINE FORMS OF TITANIUM

There are two forms of titanium first being alpha and second beta. Alpha has a hexagonal close packed(Fig.2) crystal structure and beta has body centred cubic structure (Fig. 3).[6]

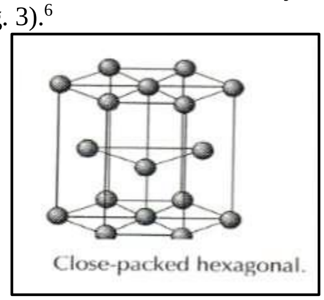

Fig. 2 Hexagonal close packed structure

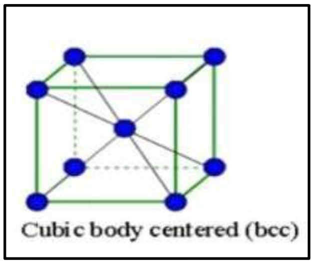

Fig.3: Cubic body centered

PHYSICAL PROPERTIES OF TITANIUM

The electronic configuration of titanium has lightly bounded$3d^2$ and $4s^2$ electrons (Fig. 4). This makes it extremely reactive, quickly forms oxide which makes it biocompatible.

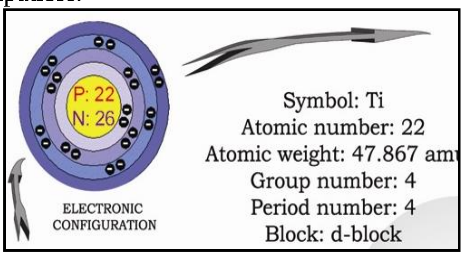

Fig. 4: Electronic configuration

At 882°C, titanium exists as hexagonal close-packed atomic structure. At this temperature, transition to body centred cubic structure takes place. At 1665°C the metal melts. The alpha phase of titanium is stabilized is the reason for the greater solubility of oxygen, aluminium, carbon and nitrogen in the hexagonal close-packed structure.

The density of Cp Ti is 4.5g/cm^3

Due to the light weight of Ti various changes in design of Ti restorations and removable prostheses is done. Properties like strength-to-weight ratio, greater ductility, and decreased thermal conductivity makes it more efficient and easy to use. If the difference of coefficient of thermal expansion between porcelain and alloy is within ±1x10-6 /°C successful bonding takes place between the two. Coefficients of thermal expansion of Ti-6A1-4V is12.43 x 10-6 /ºC, and of commercial porcelain materials is about 14 x10-6/°C.[7]

MECHANICAL PROPERTIES

The mechanical properties like greater strength and lower modulus are very beneficial for an implant material. Stronger materials helps to withstand occlusal forces without fracture or failure and decreased modulus is required to transmit these forces to the bone. Thus for any material to be a successful dental implant material its strength should be more than that of the bone and its modulus of elasticity should be close to bone.Ti-6A1-4V is the commonly used titanium alloy for dental implants mostly because of its proportion and producibility. Tensile strength of spongy bone is 83 MPa and cortical bone is 117 MPa. Elastic modulus of cp grade 1 titanium to cp grade 1V titanium are in range of 102 to 104 GPa.
The titanium alloys have double the strength and almost half the elastic modulus as that of Co-Cr-Mo alloys. When compared to 316L stainless steel, the Ti alloy has almost the same strength, but elastic modulus is half.[7]

BIOLOGICAL PROPERTIES

Titanium is an excellent material in terms of biocompatibility and predictability.
When a non-alloyed implant is placed there is an increase in the number of leukocytes around it which results in an acute inflammatory response. The number of leukocytes decreases after the first week and fibroblasts increases in the interfacial tissue. After a week of insertion of the implant the fluid space around the implant is decreased.[8]

CASTING

Casting is major problem in titanium because of
- High melting temperature
- Low density
- Increased affinity of titanium to gases like oxygen, nitrogen, hydrogen
- Reaction between titanium and investment material

Sprue design:
•For titanium casting the sprue design for co-cr alloy cannot be used.
•Porosity is greatly reduced by using large and multiple sprues.
•Attaching the sprue perpendicular to the minor connector and using a curved sprue design greatly reduces the porosities.
Internal porosity:
Internal porosity decreases the bulk and results in stress concentration thus causing fracture.

Method of inspection of porosity

- Use a standard occlusal Kodak film and place the framework upside down on top of the occlusal film
- Set the dental x-ray machine at 90kv, 25ma for 30 sec
- Allow 10cm distance between cone and framework
- Expose and process the occlusal film[9]

CP TITANIUM

VACUUM CASTING

Pure titanium melts at 1,668°Cand reacts with gases like oxygen, nitrogen and carbon and investments. Hence, pure titanium should always be cast and soldered in an oxygen free environment. When cast in centrifugal casting machine titanium flows less easily due to its low specific gravity.

LOST-WAX CASTING

Lost-wax casting method is followed for the making metallic restorations outside the mouth.[9](Figure 5)

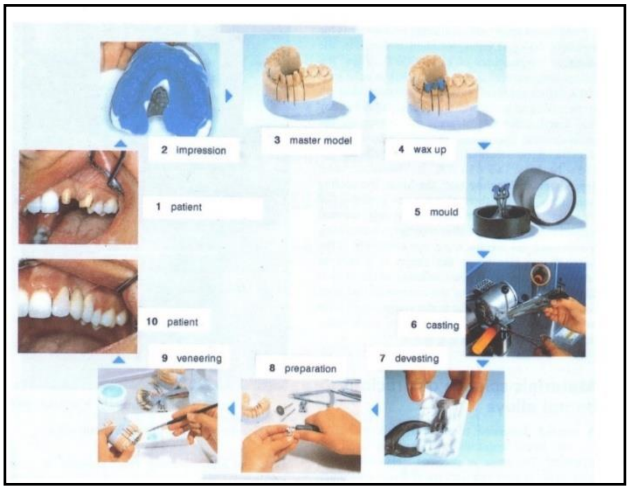

Fig. 5: Lost-wax casting method

TITANIUM CASTING SYSTEMS:

There are three types of Ti casting systems available:

- A pressure / vacuum casting system in which there are different melting and casting chamber (Castmatic, Dentaurum).
- A pressure /vacuum system in which there is only one chamber for melting and for casting (Cyclare, J Morita) and
- A vacuum / centrifuge casting system (Tycast. Jeneric / Penetron, and Titaniumer, Ohara)

In 1989 a new casting machine(Fig 6) was developed by H Hamanaka et al for the casting of titanium and Ni-Ti alloys. This machine had an argon arc vacuum pressure system with a melting chamber situated up and casting chamber below it.

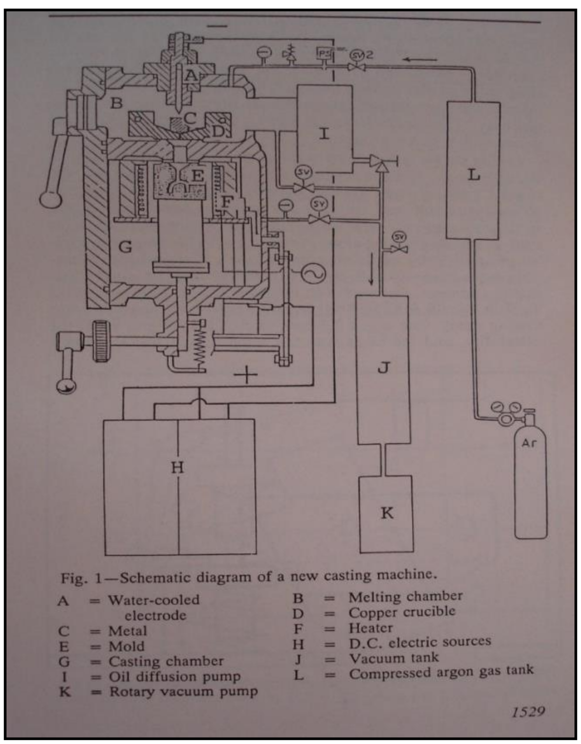

Fig 6: Casting machine

THE PROCEDURE FOR TITANIUM AND NI-TI ALLOY CASTING:-

1) The oil diffusion pump are used to evacuate the melting and casting chambers.
2) A heater is placed in the casting chamber to control the mold temperature.
3) Two types of copper crucibles are used –first a split type and second a tilting type. These two types of crucibles are interchangeable.
4) To improve the castability a device for direct suction is placed at the base of the mold.
5) For a more efficient operation the vaccum tank along with the compressed argon gas tank are set.
6) Water cooled electrodes and double D.C. electric sources are used for melting alloy of a capacity of 100g.
7) A new control system was introduced.

Once the mold and metal are set on the machine, evacuation of the upper and lower chambers were done.

After evacuation the start button was pressed and the argon gas was fed into the upper chamber which resulted in automatic starting of the electric arc at a given pressure. Once the alloy melts and the "cast" button was pushed a new control system was started.

Firstly for 0 -1 second the upper chamber is exhausted, preceeded by the splitting and tilting of copper crucible to flow the molten metal. For the next 0.01 to 0.05 seconds, compressed argon gas was pushed into the upper chamber.[10]

TITANIUM MACHINING

Machined Ti implants was the initial application of titanium in dentistry. It was developed as an alternative to the lost wax casting technique for the manufacture of unalloyed titanium crowns and fixed partial dentures by Andreason et al. A milling machine was is used to shape the external contour of the crown or coping from a solid piece of titanium and for contouring the inner surface of the crown is spark abraded with carbon electrode. This method is used for single titanium crowns where as for multiple unit fixed prosthesis is fabricated by laser welding the individual units together.[11]

TITANIUM FOR DENTAL APPLICATION

Titanium in Prosthodontics

The increasing trend involves using titanium as an economic and biocompatible replacement for the existing alloys in the fabrication of fixed, removable and maxillofacial prostheses. There is a continuously increasing urge for fixed prostheses. Implants and natural teeth are used to hold up the fixed and removable prostheses.

It is a general concept that when a fixed prosthesis has to be fabricated its metallic structure should be rigid enough to strongly support the functional masticatory forces along with the artificial teeth which are made of resin and ceramic for esthetic reasons.

Commercially pure (cp) titanium and titanium alloys which contains aluminium and vanadium, or palladium

(Ti-O Pd), are regarded as a future material for the fabrication of removable partial denture frameworks.0.70 mm thickness frameworks has better castability as compared to the conventional 0.35 mm thick Co-Cr frameworks. Also Ti frameworks fail to cast perfect mesh specimens.
Recently titanium has been used for the rehabilitation of cranial defects; maxillary and mandibular defects like cleft palate. Successful osseointegration lets the use of titanium implants in the orbital bony resin to the facial prosthesis. In anchored Hearing Aid (BAHA) retention is achieved using titanium implants.[12]

TITANIUM FOR ORAL IMPLANT

In the 60's studies were done which indicated that a firm connection can be established in between the bone and titanium only if the titanium cylinders were introduced into the bone with minimal trauma. The connection when healed could not be could not be separated. From this finding Professor Branemark introduced the idea of "osseointegration" which resulted in successful dental implants.[13]

CLASSIFICATION OF ORAL IMPLANTS

Various classifications and implant designs are available. According to the position, dental implants are divided into subperiosteal, transosteal and endosseous.

SUBPERIOSTEAL IMPLANTS:

In subperiosteal implants (Figure 7) a custom made framework is rested on the bone surface underneath the mucoperiosteum. Posts or abutments which are made to penetrate the mucosa are used to secure the prosthesis.

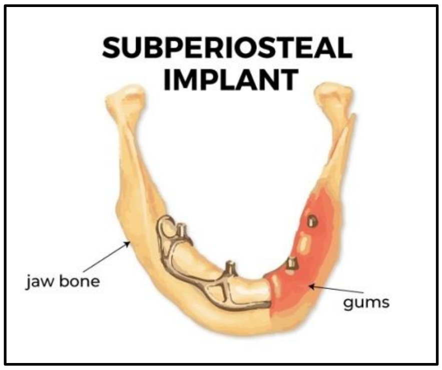

Fig 7: Subperiosteal Implant

TRANSOSTEAL IMPLANTS

Transosteal implants(Figure 8)are placed into the front of the lower jaw. Submental incison are given for insertion. The plate is fixed onto the inferior border of the mandibular symphysis and the post protrudes into the oral cavity after perforating the entire mandible and mucoperiosteum where they form the prosthestic abutments.[14]

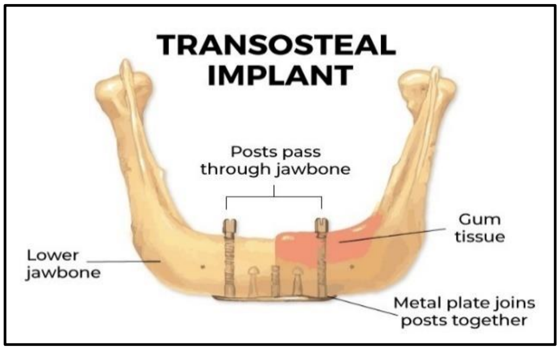

Fig 8:Transosteal Implant

ENDOSSEOUS IMPLANTS

These are the most frequently used dental implant which can be placed after a mucoperiosteal incision in both the jaws. It utilizes the concept of "osseointegration" concept. Endosseous implants(Fig 9) are further classified according to their designs : pins, needles, blades, disks and root-formed analogues (screws, cylinders, hollow-implants, truncated cones and various combination forms). Pins, needles, disks and blades are rarely used. Root formed analogues are the most commonly used. These are either made of pure titanium or Ti-6AI-4V.[15]

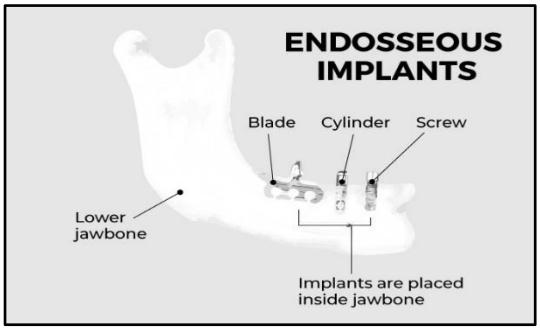

Fig 9:Endosseous Implant

Zygomatic implants are another application of titanium implants which can be used in cases of atrophic maxillary ridges. These are long implants which are inserted into the zygomatic bone in order to avoid bone grafting procedures.

CONCLUSION

Because of their superior physical and chemical properties titanium and titanium alloys are a suitable material for oral implants and prostheses. Along with its properties its biocompatibility, light weight, long range availability makes it a miracle metal for biomedical applications.

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